



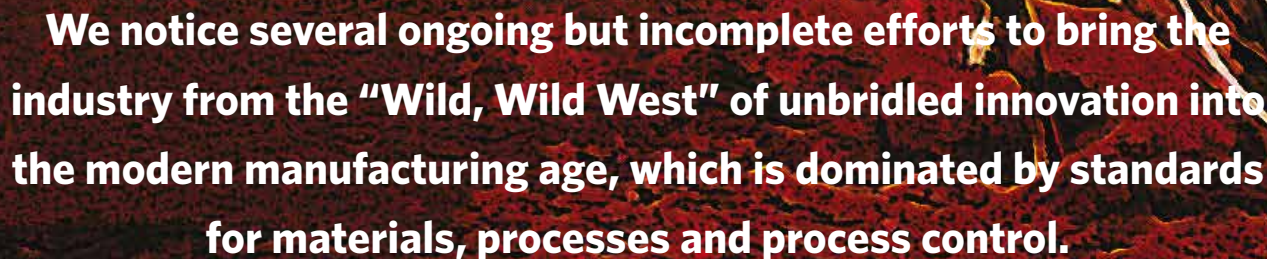
Harnessing the Potential of Additive Manufacturing

Bill Decker

Additive manufacturing (AM) has the potential to enable the Department of Defense (DoD) to manufacture parts and components closer to the point of need, offering a huge opportunity to streamline the supply system. This could lead to the reduction, or eventual elimination of warehouses, wholesale stock, moving the point of sale from the original equipment manufacturer (OEM)/supplier to the point of use. Inventories of finished spare parts would be reduced, with commensurate reduction in facilities and staff to manage them, realizing significant savings for the DoD.

The significant challenge to the AM community is the DoD's desire to maintain competition not only on the acquisition but also on the sustainment side of what is purchased to support our warfighters. The guidance provided by our leaders is to "enable competition throughout the products' life cycle." The goal is to avoid "vendor lock"—i.e., the situation in which only one vendor can meet the requirements. This can arise when only one supplier can provide the required equipment or when technical data rights are insufficient to use another contractor.

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As we look at the current state of the AM community, we notice several ongoing but incomplete efforts to bring the industry from the “Wild, Wild West” of unbridled innovation into the modern manufacturing age, which is dominated by standards for materials, processes and process control.

Conventional manufacturing is based upon a design that is documented either in a drawing or a computer-aided design (CAD) file. The manufacturing team then develops a documented public or private process for producing and replicating the part. A full performance specification for the item also is developed, along with the tests that must be passed to demonstrate the performance of the item and the repeatability of the process to produce it. A number of standards developed over the years and codified by International Standards Organization (ISO) and/or the former American Society for Test and Materials (ASTM) are used in the process, including the standard(s) for the raw material(s), process standards for each material, test standards and performance standards. Whenever possible, the standards cited are industry standards. Competitors who desire to produce the item must demonstrate that they are compliant with the design, testing, standards and meet the performance requirements. These standards enable competition in the manufacturing of spares and repairs, with multiple suppliers able to order materials from many sources and use machines from different suppliers to make an item. This approach enables the DoD to achieve its goal of competition throughout the acquisition life cycle.

When we look at additive manufacturing, we have a much different environment. To date, ASTM has only published standards for two metal materials. Summaries of the two ASTM standards:

Standard Specification for AM Production of Titanium-6 Aluminum-4 Vanadium with Powder Bed Fusion. This specification covers additively manufactured titanium-6 aluminum-4 vanadium (Ti-6Al-4V) components using full-melt powder bed fusion such as electron beam melting and laser melting. It indicates the classifications of the components, the feedstock used to manufacture Class 1, 2 and 3 components, as well as the microstructure of the components. This specification also identifies the mechanical properties, chemical composition and minimum tensile properties of the components.

Standard Specification for AM Production of Nickel Alloy.

This specification covers additively manufactured nickel alloy (UNS N07718) components using full-melt powder bed fusion such as electron beam melting and laser melting. The components produced by these processes typically are used in applications that require mechanical properties similar to machined forgings and wrought products. Components manufactured to this specification often, but not necessarily, are post processed via machining, grinding, electrical discharge machining, polishing and so forth to achieve desired surface finish and critical dimensions.

Please note a couple of things. First, these standards cover only two materials. Second, these only apply to materials processed in a full-melt powder bed fusion process. (Note: A standard also exists for a plastic material.) An additional standard exists (ISO/ASTM) for the software file format to operate the AM machines.

Let’s study the impact of this immature environment on the DoD and our policies. A hypothetical example:

An Army Program Manager (PM) for Trucks is challenged to address two requirements documented in the Capability Development Document:

1. Reduce Mean Time to Repair, which includes logistics delay time. Objective: 24 hours; Threshold: 48 hours.
2. Reduce footprint of spares by 20 percent in 2 years, 50 percent in 5 years (reduced inventory, reduced transportation, reduced management costs).

An acquisition strategy has been developed, including the following key points:

1. Implement Better Buying Power initiatives to the maximum extent possible
 - a. Maintain competition throughout the product life cycle.
 - b. Obtain technical data and technical data rights (including software) needed to support product with nongovernmental personnel.
1. The life-cycle sustainment plan must address the above requirements in all phases of acquisition.
2. Exploit new technology to provide the capability, wherever possible.


Implementing the Guidance Provided

The PM is considering using an AM process to produce the metal part of wheels) for the Army's trucks. The rationale is that wheels are large, heavy and not very sophisticated and thus are good candidates for AM. A thorough search did not find any suitable material for which an ASTM or ISO standard existed. (Neither of the above material standards is appropriate for the wheels.) The OEM produced the wheels using a stamping process, then qualified them for military use through testing and the application of current material standards. It agreed to deliver the software to enable the Army to make replacement wheels using AM, and negotiated a royalty of \$X per wheel to be paid upon production. To qualify the process, the OEM purchased raw material (metal powder) from Acme Materials and used Robots-R-Us' AM machine to make wheels for test/qualification as replacement wheels. For its machine, Robots-R-Us delivered the previously developed software that was compliant with the ASTM/ISO AM Format. The software

(He was vendor locked to Robots-R-Us and Acme!!) And the software delivered with the equipment could only be modified by government personnel. (However, it could be used, without change, by anyone.)

His boss, PM for Trucks, questioned why this could not be competed and how did the deputy PM plan to support these new AM machines? PM for Trucks, thinking he could amortize this investment across several spares, then directed the deputy to use the equipment to support the brake system, by making replacement brake calipers at the intermediate maintenance shops. On further thought, the deputy realized he now needed to direct the brake subsystem supplier, Westopem, to use Acme and Robot-R-Us, and to have more software delivered and licensed to make brake calipers.

At this point, the deputy realized that by directing the use of certain suppliers, the program would face higher costs from



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was delivered with Restricted Rights, as the government did not provide any funding for its development. More testing was required, as porosity was now an issue and the wheels had to be nonporous to prevent air from escaping. The wheels were approved for use on Army vehicles. Everything looked good at this point.

The Army decided to perform the production of replacement wheels at the Intermediate maintenance level (where staffing is a mix of military, government employees and third-party contractors) thus providing a responsive source for wheels, while only having to stock the raw material (metal powder). The deputy PM responsible for the replacement wheels realized he had a problem. There was only one qualified source of supply for this material (Acme) and only one machine that was qualified to produce replacement wheels (Robots-R-Us.) Furthermore, he now needed to provide the test equipment to qualify the wheels produced by machines operated by the Army, including porosity testing. The deputy PM now faced a major challenge: He had to equip all intermediate maintenance shops in the Army with tens of thousands of dollars worth of capital equipment and he only had one source of supply for the equipment and the raw material.

Westopem, as there would be no competition for several major pieces of equipment, software and raw materials. The deputy then went to the PM with the following:

Deputy PM's Summary of Problems

- Without standards for the raw material(s) required, it was nearly impossible to competitively procure the raw material to support AM, their current support concept.
- Without standards for the processes (such as the nickel standard above,) only machines from one manufacturer could be used, again eliminating competition. Although a standard exists for the software format, this is not sufficient to ensure consistent output, or enable the maintenance of the software by nongovernmental personnel.
- The lack of a method to qualify a machine so that every part did not require acceptance testing negated much of the cost saving.
- The costs of licensing and subsequent royalties are very difficult to control in a sole-source environment.

Deputy PM's Recommendations

- Encourage development of a robust set of standards for AM.

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- Work with contracting and intellectual property (IP) attorneys to develop an approach to licensing AM software and structuring royalties.
- Wait until the technology matures to plan on AM as a baseline for spare parts.
- Include, as an option, the technical data and software required to support an AM approach in the future.
- At this point, a demonstration program might be appropriate, but without the standards there is insufficient competition to keep prices reasonable. PM for Trucks may want to consider volunteering one of his intermediate maintenance sites as a demonstration site for developing and deploying AM.
- A related concern is how to motivate industry to accept this approach to life-cycle maintenance.

A quick discussion of the last point: Industry's business plans routinely count on the sales of spares, repairs and upgrades to the U.S. Government to obtain the return on investment (ROI) necessary to justify the investment for the initial contract. While there are precedents for licensing IP (patent license agreements are an example), these are commonly employed when the OEM either can't or won't make the quantity needed by the government. If (or when) the government fully adopts the AM paradigm, OEMs will lose some or all of their operations and support revenue stream. An approach is to use a licensing agreement, with a royalty paid for each component made, but this may be expensive. One of the government's needs is to ensure a viable defense industrial base. This can be done by providing opportunities backed up with policies and processes that promise attractive returns on investment and that entice our industry partners to invest in both research and development and in business development.

Summary

AM, as it exists today, delivers a product, and a process to replicate it by using the same materials and same material handling process at a location close to the point of consumption. The current approach is to specify a material (or materials) to be used by a specific machine to make that part and to require delivery of the computer file needed to run the machine. What has not been done is to develop the widely accepted standards for the industry, so that materials from Supplier X and from Supplier Y are totally equivalent. Widely accepted standards should also apply to the machines, for which there are many potential suppliers and no standard way to qualify them. The result is that if the DoD desires to make a part using AM, it is "vendor locked" to purchase the identical machine and identical material (from their respective vendors) and thus cannot benefit from the natural price controls that result from competition. As ISO and ASTM develop standards, different manufacturers will be able to produce the materials and machines needed to support scenarios similar to those above. IP rights issues and royalties will need to be addressed by our IP professionals, along with business models that motive our defense industrial base.



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